Automatic Testing of Transmission and Operational Functions of Intertoll Trunks

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Conditions brought about by nationwide dialing increase intertoll trunk maintenance problems substantially. Under this switching plan with full automatic alternate routing there is a considerable increase in the amount of multiswitched business, and as many as eight intertoll trunks in tandem are permissible. In addition, operator checks of transmission on the connections are lost on most calls. These factors impose more severe limitations on transmission loss variations in the individual trunks and throw on the maintenance forces additional burdens of detecting defects in the distance dialing network.

New methods of analyzing transmission performance to locate the points where maintenance effort will be most effective continue to be studied. The automatic testing arrangements described in this paper enable the maintenance forces to collect over-all transmission loss data quickly and with a minimum of effort. They also facilitate the collection of such data on groups of trunks in a form to make statistical analyses easier. The use of these testing arrangements will permit the maintenance forces to keep a closer watch on intertoll trunk performance and will assist in disclosing trouble patterns.

INTRODUCTION

The advent of nationwide dialing, especially with full automatic alternate routing, has presented additional problems in the maintenance of intertoll trunks. Transmission requirements are more rigorous, the intertoll trunk connections are more complex, and certain irregularities in the performance of the distance dialing network are difficult to detect. Automatic test equipment has been provided to aid and increase the efficiency of over-all testing. This equipment is capable of automatically

testing the operational (signaling and supervisory) functions of dial-type intertoll trunks, and of making two-way transmission loss measurements and a noise check at each end. The test results may be recorded at the originating end by means of a Teletypewriter.

Automatic trunk testing has been used for many years in the local plant for checking the signaling and supervisory features of interoffice trunks. The automatic intertoll trunk testing equipment serves a similar function with respect to these operational features of the intertoll trunks. Because published material is available on automatic operational testing,* these features will not be discussed in detail in this paper; more emphasis is given to the transmission testing features which are new.

MAINTENANCE ARRANGEMENTS FOR INTERTOLL TRUNKS

Except in the very small offices, intertoll trunks usually have a test jack appearance in the toll testboard for maintenance purposes. Cord ended testing equipment in the toll testboard positions enables the attendants to perform various operational tests and to make transmission loss, balance, noise or crosstalk measurements. Facilities are provided for communication with distant offices and with intermediate points where carrier or repeater equipment may be located. Testing of carrier or repeater equipment as individual components or systems is an important aspect of the trunk maintenance problem but is beyond the scope of the present paper.

The maintenance of intertoll trunk net losses close to their specified values is currently a most important transmission problem. Various aspects of the problem are discussed in a companion paper.†

Although the manual testing equipment mentioned above is vital to trunk net loss maintenance, the need for reduction in time and effort required to make measurements has led to the provision of semi-automatic testing arrangements. These arrangements permit a testboard attendant to check transmission in the incoming direction by dialing code 102 over a trunk. The trunk is connected to a source of one milliwatt test power at the far end and a measurement of the received power indicates the net loss. The equivalent of a semi-automatic two-way test may be obtained by making a code 102 test in each direction. If complete information on the test results is desired by one testboard attendant, the attendant at the other end of the trunk must report back his results.

* R. C. Nance, Automatic Intertoll Trunk Testing, Bell Labs. Record, Dec., 1954.

† H. H. Felder and E. N. Little, Intertoll Trunk Net Loss Maintenance Under Operator Distance and Direct Distance Dialing, page 955 of this issue.

In both the manual and semi-automatic methods of measurement, the results must be recorded manually. For statistical analysis of trunk transmission performance in terms of "bias" and "distribution grade", as discussed in the companion paper,* deviations of the measured losses from the respective specified losses must be computed and summarized mauually.

The automatic testing equipmeut described in this paper has been developed as an additional maintenance tool. It will not supplant existing arrangements discussed above but rather is intended to increase the capabilities of plant personnel to do an effective maintenance job. The following features of the equipment contribute particularly to this end:

1. Large numbers of trunks can be tested and the results recorded without the continuous attention of a testboard attendant.

2. The attendant is informed by an alarm whenever the loss of a trunk deviates excessively from the specified value.

3. Computation and summarizing of net loss deviations into class intervals are done automatically, thus facilitating statistical analysis of trunk performance.

4. Data can be collected quickly in large volume for indicating the performance of groups of trunks. Confusiou occurring with manual measurements because of changing conditions with time is reduced.

5. Stability of an individual trunk may be checked by a series of repetitive tests.

6. Semi-automatic two-way trunk tests can be made by one attendant when required.

To do an equivalent job entirely by manual methods would require an appreciable increase in the amount of manual test equipment and in the number of test personnel. A comparison of the times required for operational and transmission tests by manual, semi-automatic and automatic methods is shown in Fig. 1. The time shown for the code 102 test does not include coordination time required if information on test results in both directions is required at one end.

GENERAL DESCRIPTION OF AUTOMATIC TESTING EQUIPMENT

Automatic intertoll trunk testing requires automatic equipment at both ends of the trunk.At the originating or control end, an automatic test circuit sets up the test call and controls the various test features. In the distant offices, test lines reached through the switching train provide appropriate automatic test terminations. The automatic equipment for

* H. H. Felder and E. N. Little, Intertoll Trunk Net Loss Maintenance Under Operator Distance and Direct Distance Dialing, page 955 of this issue.

use at the control end, adapted for transmission testing, is presently available only for No. 4 type toll switching offices.

Fig. 2 is a block schematic of the arrangement for automatic intertoll trunk testing, including transmission tests. In the originating No. 4 toll crossbar office an automatic outgoing intertoll trunk test circuit is used which consists of an automatic outgoing intertoll trunk test frame and one or more associated test connector frames. These frames have been provided in all No. 4 type offices and perform the functions of setting up

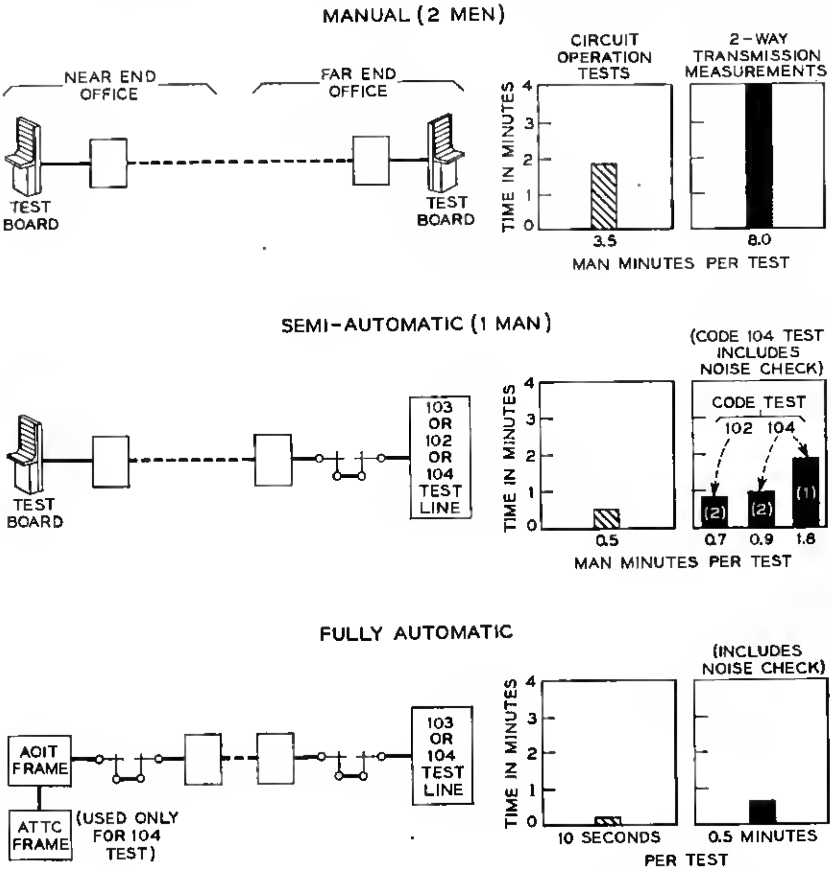

Fig. 1 — Time required for manual tests versus semi-automatic and fully automatic tests. (1) Average time per test for 52,000 field test measurements in 20 offices under normal operating test conditions (includes test preparation, time waiting to be served, testing time, and recording of results). (2) Average time per test for test measurements made in rapid sequence during light load period. The semi-automatic code 104 test includes a noise check at the far end only.

the test call and making operational tests on the intertoll trunks. For automatic transmission tests an automatic transmission test and control circuit, provided in a separate frame as an adjunct to the test frame, is brought into play. A Teletypewriter, mounted in the transmission test frame, is adapted for use with the equipment in the originating office for recording test results. The Teletypewriter is used to make a record of trunks having some defect in their operational features, busy trunks passed over without test and, during transmission tests, to record the results of the transmission measurements. The test frame and associated transmission test and control circuit and Teletypewriter are used principally by the toll test board forces and, therefore, are usually located near the toll test board. Figure 3 shows such an installation.

The intertoll trunk test connector frames in the originating office, not shown in Fig. 3, are frames of crossbar switches and there may be several such frames in a large office. Each crosspoint on the switches of the test connector frames represents an individual intertoll trunk. When a trunk is to be tested, the test frame closes the crosspoint of the test connector switches which serves that particular trunk. This extends the selecting leads (trunk sleeve and select magnet leads) of the trunk to the test frame for use in setting up the call. A class contact on the test connector crosspoint also operates one of several class relays in the test frame when the crosspoint is closed. The function of the class relay is discussed later.

The test frame has an appearance on the incoming link frame of the office switching train. The intertoll trunks to be tested appear on the outgoing link frames of the office switching train. When a trunk is to be tested, the test frame engages the office common control equipment (decoder and marker), through a connector, and requests a path between the test frame appearance on the incoming link frame and the particular intertoll trunk which is to be tested. The common control equipment is able to set up this path since the test frame has closed a test connector cross-point to bring the selecting leads of the trunk to be tested into the test frame. The common control equipment uses the select magnet lead to identify the trunk to be tested and thus is able to set up the path to that particular trunk. The test frame uses the trunk sleeve lead for busy test purposes and for controlling the test call.

In the distant offices separate groups of test lines provide automatic test terminations for operational and transmission tests, respectively. These are reached through the switching train as indicated in Fig. 2. The three digit service code 103 is reserved in toll switching offices for reaching the operational test lines and code 104 is reserved for reaching the transmission test lines. A transmission measuring and noise checking

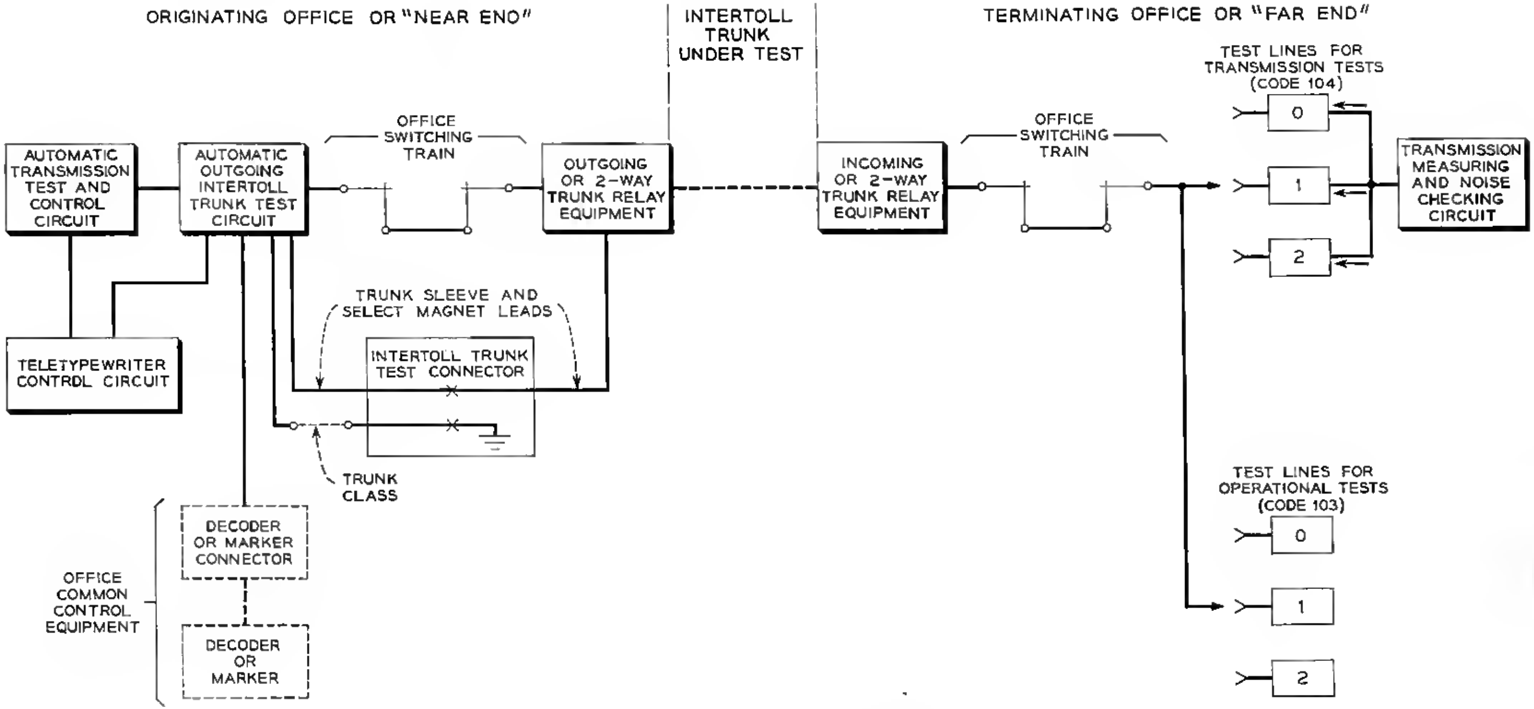

Fig. 2 — Arrangement for automatic tests.

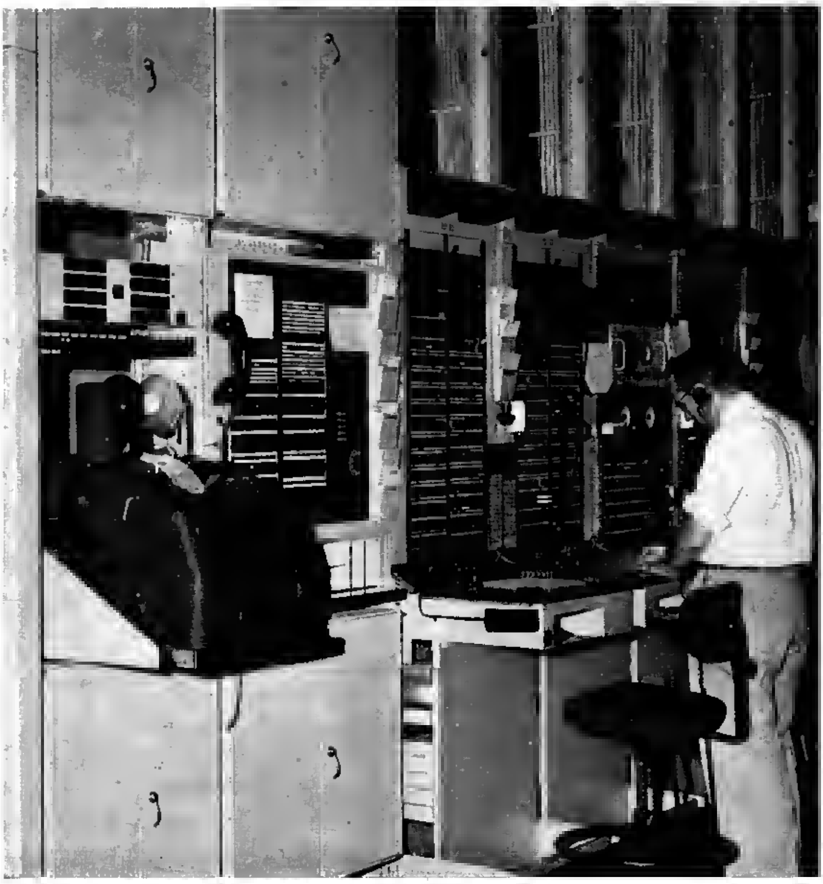

Fig. 3 — Automatic intertoll trunk testing equipment.

circuit, sometimes referred to as "far end equipment," is associated with the group of code 104 test lines for performing the transmission measurements. When simultaneous transmission test calls arrive in the distant office from different originating offices, the calls wait on the code 104 test lines and are served by the transmission measuring and noise checking circuit, one at a time, in their proper turn.

After the trunk test frame has obtained a path through the switching train in the originating office to the trunk to be tested as explained above, it pulses forward over the trunk the desired test line code, either code 103 or code 104. In response to the code, the switching equipment in the distant office sets up a path through the switching train to one of

the code 103 or code 104 test lines. A steady off-hook signal is returned over the established connection to the test frame at the originating office to indicate that the test may proceed.

The process of setting up a test call, as described above, simulates very closely the procedures followed in setting up a normal call from an incoming trunk in the originating office to a desired number in the distant office. Therefore, any irregularities in the operational features while setting up the test call will be detected by the test frame and will result in appropriate trouble indication at the test frame at the originating end.

The automatic testing arrangements will operate with offices where terminating calls are switched either on a terminal net loss (TNL) or on a via net loss (VNL) basis. This is done by including appropriate pads for use at VNL offices.

FEATURES OF INTERTOLL TRUNK TEST FRAME

Control of Test Connector

When the trunk test frame is put into operation, it closes the first crosspoint of the first test connector crossbar switch on the test connector frames to prepare for testing the first trunk in the test sequence. When the trunk test is completed, the test frame advances to the next crosspoint for testing the next trunk. This progression continues through all the test connector frames until all intertoll trunks in the office have been tested. The test frame stops when the test cycle is completed. Particular circuit selection keys are provided on the test frame so that the test connector can be directed manually to any point for testing an individual trunk or for starting a test cycle at some intermediate point in the test sequence, rather than with the first trunk. As the test frame progresses through a test cycle, it also displays on lamps a 4-digit "trunk identification number" corresponding to the test connector crosspoint which is closed. When a trouble is encountered, the attendant uses this 4-digit number to identify the trunk being tested as a particular trunk to a particular destination. The Teletypewriter prints the trunk identification number as a part of each trunk test record.

Busy Test

Before starting a test, the test frame tests the trunk sleeve lead for busy. If the trunk is busy, the test frame waits for the trunk to become idle. A "pass busy" key is provided which, when operated, cancels the waiting period and causes the test frame to immediately pass over busy

trunks to save time. The circuits are arranged so that, if desired, the Teletypewriter may print a record of busy trunks passed over without test. By means of a timing key this record can be delayed two minutes or four minutes to wait for the trunk to become idle. This is used when it is preferable to wait a reasonable time for trunks to become idle to secure tests on a larger proportion of the trunks.

Trunk Classes

A class relay, operated by a contact on the test connector crosspoint as previously mentioned, indicates to the test frame the type of trunk being tested so that it can properly handle the test call. There are 33 of these relays. A flexible cross-connection in the path of the class contact on each test connector crosspoint permits each crosspoint to be assigned to the particular one of the 33 class relays which represent the characteristics of the intertoll trunk associated with that crosspoint. Twenty-eight of the class relays are used in connection with trunks on which automatic transmission tests are made and indicate, among other things, the specified loss of the trunk being tested. These relays are provided in such a manner that, for any trunk, a class can be chosen which agrees with the specified loss of the trunk to within ± 0.1 db over the range 3.8 db to 12.1 db. The specified loss is used by the automatic transmission test and control circuit when computing the deviation of the measured loss from the specified value, as covered later.

Test Cycles

The test frame may be set up by means of control keys to perform various kinds of test cycles. Some of these test cycles are described briefly below.

Code 103 Tests. A complete check is made of all the circuit operating features including the ringing and the supervisory features while the connection is established. If this test is passed successfully, one may assume that the intertoll trunk circuit and the associated signaling channel will properly handle normal calls although this does not prove that the transmission performance is satisfactory.

Signaling Channel Tests. This is an abbreviated code 103 test to verify the integrity of the trunk and its signaling channel. It can be made quite rapidly and is useful for checking the correctness of patching after day and night circuit layout changes.

Pass Idle Test. This is a test cycle which may be run occasionally during a very light load period to detect trunks which may be falsely busy.

Repeat-2 Tests. This consists essentially of two code 103 tests on the same trunk in rapid succession. It is used to insure that a connection through the switching train in the distant office will be properly broken down when a call is completed.

Repeat Test. A "repeat test" key on the test frame cancels the advance of the intertoll trunk test connector. Since the test frame cannot then advance to the next test connector crosspoint, it tests the same trunk repeatedly. This is useful for verifying a trouble condition and for detecting an intermittent trouble, or for obtaining data on stability versus time.

Manual Tests. When the test frame is set up for making manual tests, it engages the office common control equipment to set up a path through the switching train to the trunk to be tested but does not pulse forward code 103 or 104. Instead the attendant can pulse forward the proper code to reach the toll test board at the distant end. This permits dial type trunks to distant offices, not equipped with test lines, to be tested manually.

Code 104 Tests. A 3-position key controls transmission testing. When the key is normal, the test frame makes operational tests. When the key is operated to the transmission and noise position, a two-way transmission loss measurement is made and is followed by a noise check at each end of the trunk. When the key is operated to the transmission only position the noise checks are omitted. The latter position is used when it is permissible to omit the noise checks to save time. When making code 104 tests, the test frame sets up and breaks down the test connection in the same way as when making code 103 tests and, while the connection is established, it receives supervisory signals from the far end. Thus most of the trunk operating features, except for ringing, are also checked as an incidental part of the transmission test. Irregularities in the circuit operating features can result in a trouble indication in the same way as when making operational tests.

Trouble Indications

During a test, progress lamps display the progress of the test call and, when trouble is detected, one of a number of trouble indicating lamps may also be lighted. The progress and trouble indicating lamps indicate the general nature of the trouble.

When the Teletypewriter is not in operation, a trouble indication causes the test frame to stop, to hold the trunk busy and to sound an alarm while awaiting the attention of the attendant. It is the usual practice for the attendant to make a repeat test on the same trunk to

verify the trouble condition. He notes the nature of the trouble from the progress and trouble indicating lamps and then causes the test frame to resume testing by advancing it to the next trunk with a manual advance key.

When the associated Teletypewriter is provided and operating, it is not always necessary to sound an alarm and thus interrupt the regular work of the attendant. Instead the Teletypewriter may print a trouble record. For this purpose troubles are grouped into 18 categories. When a trouble is detected, the Teletypewriter prints a record of the trunk identification number together with a letter in a separate column indicating one of these categories. The test frame then usually makes a repeat test on the same trunk to verify the trouble except when the connection must be held, as discussed later. If the second test is satisfactory, the trouble was of a transient nature and the test frame resumes testing, leaving a single line trouble record on the Teletype tape. If the trouble is still present on the second trial, a second record is printed on the next line for the same trunk.

If the nature of the trouble, as indicated by its category, is such as to render the trunk unfit for service, the test frame will stop after the second trial, hold the trunk busy, and sound an alarm to attract the immediate attention of the attendant. If, however, the trouble is of a minor nature that can be tolerated temporarily, the test frame advances automatically to the next trunk after the second record is printed, and resumes testing without sounding an alarm. By periodic inspection of the Teletype record the attendant can note those trunks needing maintenance attention by means of the double line trouble records. A test cycle can thus be completed with the minimum of supervision on the part of the attendant.

When the nature of a trouble is such that its identity is likely to be lost if the original connection is broken down, e.g., failure of a holding ground, the test frame will not attempt a second trial but stop, hold the trunk busy, and sound an alarm. Failure to complete a transmission test satisfactorily is included in this class because such failures can be due to the testing equipment itself.

AUTOMATIC TRANSMISSION TESTS

Basic Scheme of Measurement

An automatic transmission loss measurement consists essentially of adjusting the loss of a pad at the receiving end of the trunk to bring the test power level at the pad output to a fixed value. A functional diagram of the arrangement is shown in Fig. 4.

Tbe standard one milliwatt source of test power is used at the sending end. The receiving end includes an amplifier, a set of adjustable resistance pads which are relay controlled and an amplifier-rectifier with a measuring relay (M) in its output circuit. Relay (M) is a polarized relay of a typo widely used in the telephone plant.

The amplificr has a fixed gain of 19.9 db and it includes considerable negative feedback so that its gain is constant. The pad components are precision resistors to insure accuracy.

The amplifier-rectifier consists of a two-stage amplifier followed by a rectifier tube and a detector tube for controlling relay (M). This eircuit is designed so that the margin between the input power which will hold relay (M) operated and the input power which will insure that relay (M) will release is less than 0.1 db. The gain is adjusted, by means of a potentiometer, so that relay (M) will operate when the test power level at the output from the receiving pads in Fig. 4 is one milliwatt or higher and so that it will release when the power level at this point is 0.1 db or more below one milliwatt. This close margin between operate and release permits relay (M) to be used as an accurate measuring device with a preeision eomparable with that of manual transmission measuring equipment using direct reading meters. Negative feedback, built into the amplifier portion of the amplifier-rectifier, insures gain stability and the amplifier-rectifier will maintain its gain adjustment over a long period.

When making a transmission loss measurement, the power from the sending end operates relay (M) in the amplifier-rectifier. The loss in the receiving pads is then increased, by means of control circuitry, until the power level at their output is reduced to one milliwatt. In making this adjustment, relay (M) is used as the power level indicating device. When this adjustment is finished the trunk loss will be

$$\text{Intertoll Trunk Loss} = 19.9 \text{ db} - \text{Reeeiving Pad Loss.}$$

Adjustment of Receiving Pads

The receiving pads, shown in Fig. 4 consist of 9 individual pads having losses of 10, 5, 4, 2, 1, 0.5, 0.4, 0.2 and 0.1 db. Each pad is inserted into the input circuit to the amplifier-rectifier by the operation of a corresponding pad control relay. Adjustment of the pad loss takes place in steps.

When relay (M) operates on arrival of the test power, the control circuit operates relay 10 to insert the 10 db pad. If this reduces the test power level at the output from receiving pads to a value below one milli-

watt, relay (M) in the amplifier-rectifier will release. The control circuit then releases relay 10 also to remove the 10 db pad before it proceeds to the next step. If the test power level remains one milliwatt or higher after the 10 db pad is inserted, relay (M) remains operated. The control circuit then locks relay 10 in its operated position to retain the 10 db pad before it proceeds to the next step. In the next step, pad control relay 5 is operated to insert the 5 db receiving pad. The 5 db receiving pad will then be rejected or retained, as described above, depending upon which position relay (M) takes after the 5 db pad is inserted. This process continues until all 9 individual receiving pads have been tried in descending order ending with the 0.1 db pad. When this process is completed, the combination of the 9 pad control relays which remain locked in the operated position determines, additively, the receiving pad loss and consequently, this combination is related directly to the trunk loss. At the originating or control end this combination of operated relays will be translated to the measured loss of the intertoll trunk being tested, when the results of the measurement are recorded. The method of transmitting the measured loss from the far end to the originating end is discussed later.

The transmitting and check pads shown in Fig. 4 are a separate set of pads also controlled by the pad control relays. At the start of the test the total loss in these pads is 19.9 db. Whenever a pad control relay operates to insert a receiving pad, it removes an equal loss from the transmitting pads. Therefore, when the receiving pad adjustment is finished, the loss remaining in the transmitting pads will be equal to the loss of the trunk. Also, the sum of the losses in the two sets of pads is always 19.9 db regardless of the trunk loss being measured, provided all pad components and all pad control relay contacts are in perfect order. This condition permits a precise accuracy check to be made, as discussed later.

Whenever the control circuit leaves pad control relay 4 or 0.4 in its operated position to retain the 4 db or 0.4 db pad, the subsequent 2 db and 1 db or 0.2 db and 0.1 db pad control relays are disabled. There will will then be no action as the control circuit passes through the 2 db and 1 db or the 0.2 db and 0.1 db steps. This limits the maximum receiving pad loss to 19.9 db, which is the maximum range of the automatic measurement. This range amply covers the range of losses of intertoll trunks in a usable condition. Loss measurements attempted outside the range of 0 to 19.9 db will cause failure of the built-in checks, mentioned later, and will result in an alarm at the control end of the trunk.

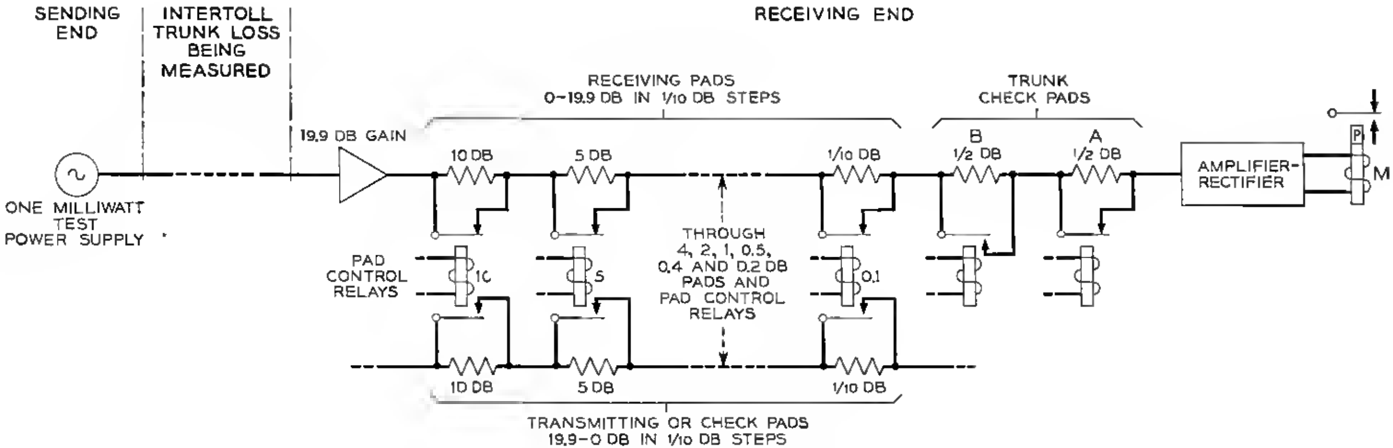

Fig. 4 — Schematic of transmission measurement.

Accuracy Checks

If the receiving pad adjustment has been successful, the power level at the pad output will be very close to one milliwatt and the measuring relay (M) will be just on the verge of moving from its front to its back contact, or vice versa. Errors may creep in, however, to prevent these things from being true. Some such sources of error are:

(1) One or more of the pad control relays might fail to lock in the operated position when they should, or fail to release when they should. It would then be impossible to adjust the total receiving pad loss to the correct value.

(2) The trunk loss might change suddenly while the pad adjustment is in progress and make it impossible, with the pads remaining to be tried, to bring the power level at the pad output to one milliwatt.

(3) The amplifier or amplifier-rectifier gains might increase or decrease due to a defective component.

(4) The milliwatt test power supply might deviate from the standard value.

(5) Defective components or faulty control relay contacts might cause the individual pad losses to be incorrect.

To detect errors of the type in items (1) and (2) a "trunk check" is made immediately after the pad adjustment is finished. Referring to Fig. 4, two 0.5 db pads, A and B, are provided in the input circuit to the amplifier-rectifier, pad A being normally out. Before the sending end removes the test power, pad A is inserted, momentarily. The resulting decrease in input power to the amplifier-rectifier should cause relay (M) to release. Both pads A and B are then cut out. The resulting increase in input power should cause relay (M) to operate. If relay (M) fails to pass either of these checks the receiving pad loss is in error by 0.5 db or more and another trial is needed to secure a more accurate adjustment. Premature removal of the test power at the sending end would, of course, cause relay (M) to fail on the second check and result in another trial.

Immediately after the trunk check and while pad B is still cut out, the receiving end rearranges its circuit locally as shown in Fig. 5 for a "loop check" to guard against errors of the types mentioned in items (3), (4) and (5) above. This rearrangement inserts a 0.3 db pad in place of the 0.5 db pad B, which is cut out. The local milliwatt supply then applies power to the amplifier-rectifier at a level about 0.2 db higher than necessary to operate relay (M). Relay (M) will fail to operate and pass this check if the combined effect of any decrease in the value of the milliwatt test power supply, any decrease in the amplifier and the amplifier-rectifier gains and cumulative errors in the receiving pads and check pads adds more than 0.2 db loss. After the above check, a 0.5 db loss is

added in the looped circuit. This reduces the input power to the amplifier-rectifier about 0.2 db below that which causes relay (M) to release. Relay (M) will remain operated and fail to pass this check if the combined effect of increases in the milliwatt test power supply or amplifier and amplifier-rectifier gains and cumulative errors in the pads exceeds 0.2 db gain. By means of the loop check the maintenance forces will be notified whenever the measuring equipment drifts more than ±0.2 db from the initially calibrated setting.

After the loop check the receiving end restores its circuit to the original connections shown in Fig. 4 and by means of relays not shown, cuts out all of the receiving pad loss. Relay (M) then reoperates. The circuit rests in this condition to await the removal of the test power at the sending end.

When the sending end removes the test power, relay (M) releases. If all accuracy checks have been passed successfully, the receiving end then prepares for the next phase of the test. If, however, the accuracy checks failed in any respect, the receiving end restores its circuit to the original condition at the start of the measurement and returns a signal to the sending end to request reconnection of the test power for another trial.

Intertoll Trunk Loss Measurement and Noise Check

An intertoll trunk loss measurement consists of two successive one-way measurements, as described above, one for each direction of transmission. The transmission test call is set up to one of the code 104 test lines in the distant office. If the transmission measuring and noise checking circuit at the far end is already engaged because another call arrived

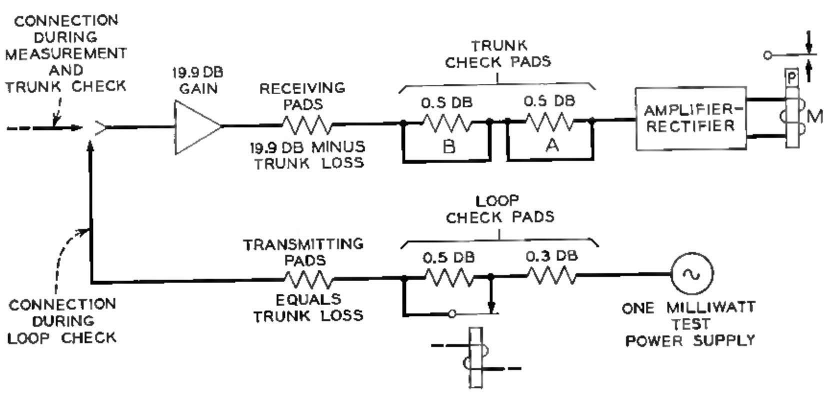

Fig. 5 — Arrangement for loop check.

just previously from some other originating office, this call waits on the test line. When the transmission measuring and noise checking circuit is ready to serve this call, it connects to the test line on which this call is waiting and then returns a steady off-hook signal to the originating end. This notifies the originating end that the transmission test may begin.

The philosophy of a two-way transmission measurement is as follows. The near end sends test power over the trunk and the far end measures the loss as previously described. In this process the loss of the transmitting pad at the far end is adjusted to a value equal to the trunk loss in the near to far direction. The far end then returns test power, first directly over the trunk and next, through the transmitting pad. The power levels received at the near end are a measure of first, the trunk loss in the far to near direction and next, the sum of the losses in the two directions. Measurement of these levels provides data for recording the loss in each direction at the near end.

The two-way transmission measurement takes place in four steps as shown in Fig. 6. These steps are described below.

Step 1

The near end sends one milliwatt and the far end adjusts its pads and checks the measurement. After about 3 seconds the near end removes the test power and then pauses for a short interval to wait for a signal denoting whether or not the accuracy tests were successful.

If they were unsuccessful, the far end will restore itself to the condition prevailing at the start of Step 1 and will also return a short (about ½ second) on-hook signal to the near end. The near end then reconnects the test power for three seconds for another trial. The test frame at the near end stops and sounds an alarm after a third unsuccessful trial.

If the far end is successful in any one of the first three trials, an on-hook signal will not be returned to the near end when the test power is removed. The near end, after the short pause, then sends a short spurt of test power which reoperates the measuring relay at the far end. This signal at the far end, after a successful Step 1, indicates to the far end that this is a full automatic test.

Step 2

For Step 2 the near end connects a far-near amplifier, a set of far-near receiving pads and an amplifier-rectifier. The far end disconnects its receiving equipment and returns one milliwatt over the trunk. The far-near receiving pads at the near end are now inserted in the proper com-

bination to reduce the power level at their output to one milliwatt. The combination of the nine far-near pad control relays remaining operated after the adjustment is finished will be translated later to measured loss of the intertoll trunk in the far to near direction. After about 3 seconds the far end removes the test power and pauses for a short interval. This completes Step 2. Each end then prepares for Step 3.

Step 3

For Step 3 the near end retains the far-near amplifier and the setting of the far-near receiving pads and adds a near-far amplifier and a set of near-far receiving pads in tandem in the input circuit to the amplifier-rectifier. The far end, after the short pause, again sends one milliwatt but this time it sends through the transmitting pad which was adjusted in Step 1 to represent the near-to-far trunk loss. The near-far receiving pads at the near end are now automatically arranged to reduce the power level at their output to one milliwatt.

In the adjustment of Step 2 the over-all loss, including the trunk in the far-to-near direction, the far-near amplifier and the far-near receiving pads, was made 0 db. Consequently, the net loss being measured in Step 3 is simply that of the transmitting pad at the far end, which is the same as the trunk loss in the near-to-far direction. Therefore the combination of the 9 near-far pad control relays remaining operated after Step 3 is finished can be translated to measured loss of the intertoll trunk in the near-to-far direction. After about 3 seconds the far end will remove the test power to complete Step 3 and it will then pause for a short interval before proceeding with Step 4.

At the near end there are also two sets of check pads, not shown, which are associated with the far-near and near-far receiving pads, respectively, as indicated in Fig. 4. During Step 2 and Step 3 the near end makes the trunk check previously described to verify the accuracy of the pad loss settings and, in addition, in Step 3, rearranges its circuit in the manner shown in Fig. 5 for the loop check. Thus at the near end the two sets of check pads, the far-near and near-far amplifiers, and the two sets of receiving pads are all connected in tandem for the loop check.

During the short pause following Step 2 and Step 3 the far end reconnects its amplifier and amplifier-rectifier as shown for Step 1 in Fig. 6. If the near end is unsuccessful in the trunk check in Step 2 or in either the trunk check or loop check in Step 3, it will restore the circuit to the original condition at the beginning of Step 2 and will also send a short spurt of test power to the far end as shown for Step 1 in Fig. 6. This reoperates the measuring relay (M) at the far end momentar-

ily. The far-end then repeats Steps 2 and 3 for another trial. The test frame at the near end will stop and sound an alarm after a third unsuccessful attempt.

If the trunk loss in the near-to-far direction exceeds 10 db, the loss in the transmitting pad at the far end will exceed 10 db. Under this condition the far end will, prior to Step 3, remove 10 db loss from the transmitting pad to increase the test power level on the trunk. This is done to improve the test power level-to-noise ratio and to reduce the error when measuring losses of intertoll trunks having apparatus whose loss is dependent on signal amplitude. The far end will also return to the near end a short on-hook signal. This on-hook signal at the near end, just prior to Step 3, is an "add 10" signal and causes the near end to add 10 db to its loss measurement in Step 3, to compensate for the loss which was removed at the far end.

Immediately after Step 3, if the transmission test control key on the test frame is in the transmission only position, the test frame will cause the teletypewriter to record the results of the measurements and will then break down the connection and advance to the next trunk. If the transmission test control key is in the transmission and noise position, the test frame will wait after Step 3 for each end to complete a noise check in Step 4.

Step 4

For Step 4 the near-end removes its near-far amplifier and the near-far and far-near receiving pads and increases the gain of the amplifier-rectifier for a noise check at the near-end. Likewise, the far-end removes the receiving pads and increases the gain of the amplifier-rectifier for a noise check at the far end. Each end rests in this condition while the amplifier-rectifier at each end integrates the noise voltage over a 5-second interval. If the integrated value of noise voltage at either end exceeds a predetermined value, the amplifier-rectifier at that end will operate measuring relay (M) in its output which causes a high noise condition to be registered at that end. If neither end registers a high noise condition, the test call proceeds to completion without a noise indication being recorded at the near end.

When the transmission measuring and noise checking circuit at the far end completes the noise check, it releases itself from the test line and is then free to serve a new call while the test line returns an on-hook signal to notify the originating end that the test is completed. This will be either a steady on-hook signal if the far end has not registered a high

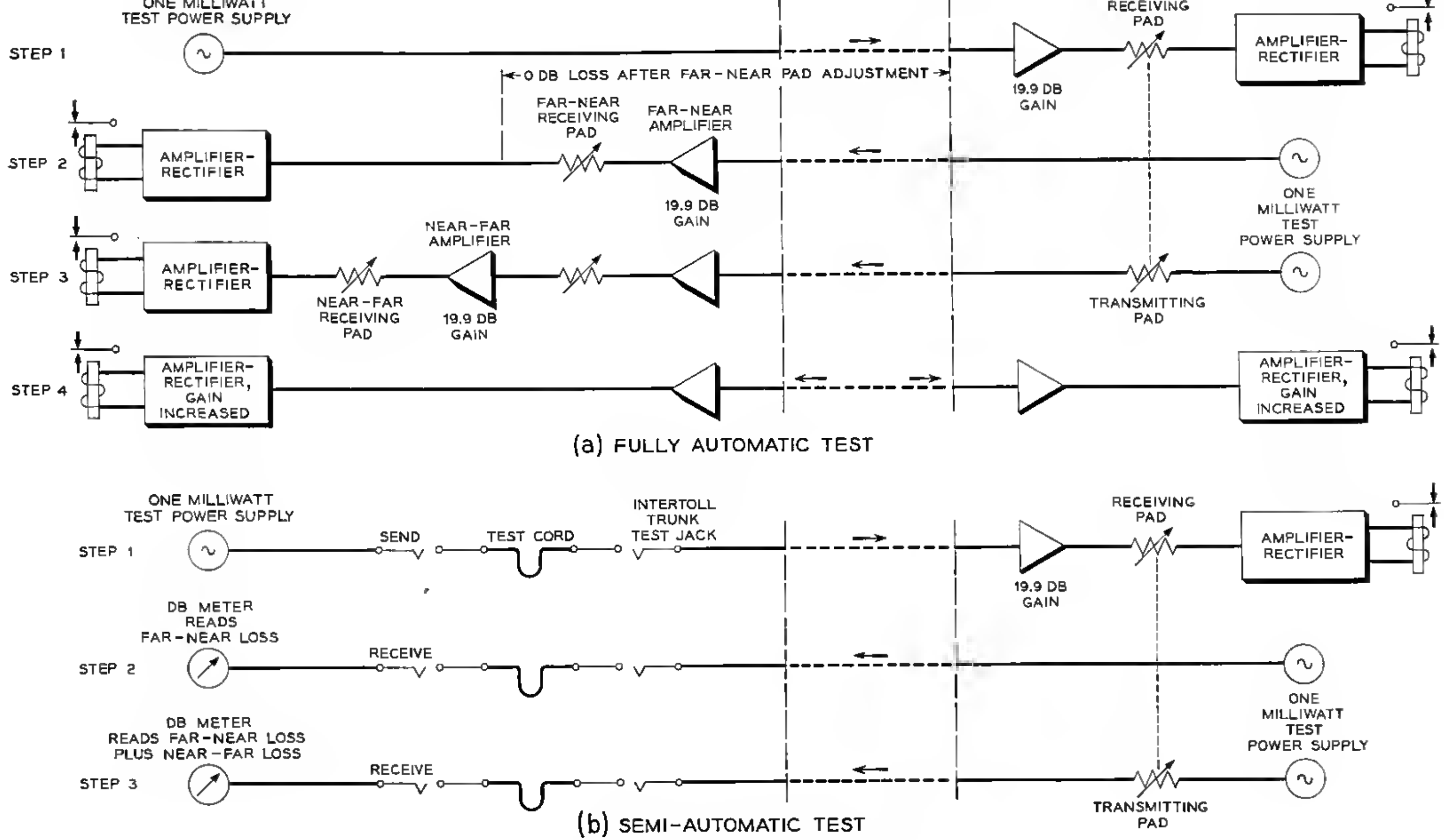

Fig. 6 — Two-way transmission test.

noise condition, or a 120 IPM flashing signal if the far-end has registered a high noise condition. The near end is thus advised of the results of the noise check at the far end. The test frame, on receipt of this signal, causes the Teletypewriter to complete the record and then breaks down the connection and advances to the next trunk.

The amplifier, which precedes the amplifier-rectifier includes a network which provides F1A noise weighting during the noise check. The amplifier-rectifier is adjusted in the noise checking condition (that is, when its gain is increased) so that a noise indication will be given when the noise exceeds about 35 or 40 or 45 dba. Since this test is intended only as a rough check to detect any abnormal noise condition, the noise rejection limit used in any given office will be governed by the types of intertoll trunk facilities terminating in that office. No correction is made for the measured loss of the trunk at the time of the noise check, hence the noise is checked at the receiving switchboard level. For the usual types of noise the results of the noise check agree roughly with those which would be obtained by an average observer using a 2-B Noise Measuring Set for a similar "go-no go" type of check.

As is evident from the previous description, each end is expected to complete the various steps of its functions within allotted time intervals. Timing intervals at the far end are controlled by a multivibrator circuit. Timing at the near end is controlled by a similar multivibrator in the intertoll trunk test frame. To insure that the test circuits always perform as they should and that the timing circuits are functioning properly, checks are built into the circuits so that anything which prevents the successful completion of a 2-way measurement on schedule causes the automatic outgoing intertoll trunk test frame at the near end to stop, hold the trunk busy and sound an alarm while awaiting attention of the attendant. The transmission measuring and noise checking circuit at the far end will, however, release itself from the test line so that it will be free to handle other calls.

Semi-Automatic Test

One-milliwatt test power supply outlets have been provided in toll offices for some time for making a one-way transmission measurement frequently referred to as a code 102 test. A test board attendant can reach the one milliwatt test power supply by pulsing forward code 102 or by requesting an operator at the distant end of a manual trunk for a connection. The test power is applied at the distant end for about 10 seconds during which time the attendant measures the loss in the receiving (far-to-near) direction. This is a fairly fast semi-automatic test but, of

course, has the disadvantage that it is a one-way test and cannot be used for all purposes.

In order to provide a semi-automatic two-way test, the far-end equipment is arranged so that a test board attendant can make a code 104 measurement unassisted. This measurement is carried out in 3 steps as shown in the lower portion of Fig. 6.

Step 1

The attendant connects a test cord to the test jack of the intertoll trunk and pulses forward code 104 using his test position dial or key set. When the far end is ready, it returns an off-hook signal which retires the test cord supervisory lamp. He then connects the other end of the cord to the one milliwatt test power supply. The far end then adjusts the receiving and transmitting pads in the same way as for a full automatic test. After about 3 seconds the attendant disconnects the test power and at that time observes the cord supervisory lamp; a single flash indicates that the far end was unsuccessful and is requesting a second trial. If the supervisory lamp remains steadily dark he connects the cord to the receive jack of his transmission measuring circuit to prepare for Step 2.

Step 2

The far end will pause about 2 seconds after the attendant removes the test power to give him time to prepare for Step 2. During this pause the far end will not receive a short spurt of test power as in the case of a full automatic test. Consequently, after the 2 second interval the far end will return one milliwatt for 10 seconds on a semiautomatic test to give the attendant time to complete a measurement. The received power is read directly on the meter of the transmission measuring circuit and is the loss in the far-to-near direction. When the far end removes the test power, the meter reading drops back to the position of no current (infinite loss) and at that time the attendant observes the cord lamp. A single flash at this time is an "add 10" signal and indicates that 10 db should be added to the next measurement. A steady dark lamp indicates that the next measurement should be recorded without correction.

Step 3

After about 2 seconds delay to give the attendant time to record the first measurement, the far end again returns 1 milliwatt, this time through the transmitting pad set up in Step 1. The meter now reads the

loss of the trunk plus the loss of the transmitting pad at the far end. Since the transmitting pad loss equals the trunk loss in the near-to-far direction, the difference between the measurements in Step 3 and Step 2 is the trunk loss in the near-to-far direction. After about 10 seconds the far end removes the test power and starts the noise check in the same way as if this were a full automatic test.

When the far end removes the test power after Step 3, the attendant leaves the connection intact until the cord supervisory lamp lights to indicate completion of the noise check at the far end. A flashing lamp indicates that the noise at the far end exceeds the prescribed limit and a steadily lighted lamp indicates the noise at the far end is below this value. A noise test at the near end may be made by the attendant if he judges, after a listening test, that a noise test is desirable. For this test he uses the standard noise measuring equipment.

PRESENTATION OF TEST RESULTS

When making operational tests and a Teletypewriter is not being used, troubles are registered by means of an audible alarm and accompanying display lamps. When making transmission loss measurements, however, a complete record of the measurements on all trunks tested, both good and bad is frequently needed. A Teletypewriter then becomes a practical necessity; otherwise the attendant would be required to supervise the automatic equipment continuously and to record, from a lamp display or similar indication, the results of each measurement as it was made. Having provided the Teletypewriter for transmission testing, its ability to print letters to represent trouble indications is utilized to avoid halting the progress of the tests when operational troubles are experienced, except when completely inoperative conditions are encountered.

Computer Circuit

As mentioned earlier intertoll trunk transmission performance is rated in terms of bias and distribution grade which are calculated from the deviations of the measured losses of the intertoll trunks from their specified values. For such calculations the maintenance forces are, therefore, more interested in the deviations than they are in actual measured losses. Accordingly, the automatic transmission test and control circuit at the near-end has a computer built into it which will compute the deviation for each measurement so that the deviation can be recorded by the Teletypewriter.

The computer is a bi-quinary relay type adder similar to those used

for other purposes in the telephone plant, for example, in the computer of the automatic message accounting system. It obtains the specified net loss of the trunk being tested from the class relay which remains operated throughout the test. When a computation is to be made of the deviation in the far-to-near direction, for example, the control circuit extends to the adder a number of leads from the contacts of the far-near pad control relays. Some combination of the 9 far-near pad control relays remains operated after the far-near pad adjustment is finished and therefore some combination of the leads extended to the adder will be closed. These leads furnish to the adder the measured loss of the intertoll trunk in the far-to-near direction. The adder then subtracts the specified loss from the measured loss and presents the answer together with the proper sign, + or −, to the teletypewriter for a printed record. The deviation in the near-to-far direction is computed in the same manner by extending corresponding leads from the near-far pad control relays to the adder at the proper time.

Deviation Registers

In determining bias and distribution grade by the method discussed in the companion article,* the deviations from specified net loss are calculated for each measurement. These deviations are grouped together in 0.5 db increments from +8 db to −8 db, all deviations exceeding +7.8 db or −7.8 db being considered as +8.0 db and −8.0 db respectively. For example, all deviations of +0.3 db to +0.7 db, inclusive are considered to be +0.5 db and are so tallied on the data, or stroke, sheet.

To assist in this work the automatic test equipment includes thirty-three manually resettable counters corresponding to the 0.5 db increments from +8.0 db to −8.0 db inclusive. Just prior to a transmission test cycle all these counters are reset to zero. At the time a deviation computation is made, the computer also causes the proper counter to register one count. After the test run on a group of trunks, the counter readings can be transcribed directly as the final tally on the stroke sheet and may be used to determine the bias and distribution grade. A "total tests" counter keeps a tally of all the computations. At the end of the test run the total count serves as a check of the total count of the other 33 counters.

Check for Excessive Deviations

In addition to obtaining data for the calculation of bias and distribution grade, the maintenance forces would also like to know promptly

* H. H. Felder and E. N. Little, Intertoll Net Loss Maintenance Under Operator Distance and Direct Distance Dialing, page 955 of this issue.

when the loss of an intertoll trunk deviates an abnormal amount from its specified value. The maintenance practices currently require that, whenever an intertoll trunk is found to have a deviation of ± 5 db or more in either direction, the trunk should be removed from service immediately and the cause of the abnormal deviation corrected. Accordingly, the computer circuit includes an alarm feature which sounds an alarm to attract the immediate attention of the attendant whenever the computed deviation is ± 5.0 db or greater.

The maintenance forces may also like to know promptly about trunks with wide deviations but which are not so bad as to require immediate removal from service. For this purpose the computer also includes a limit checking feature. This can be set, by means of optional wiring, to detect deviations in excess of ± 3.0 db, ± 4.0 db or ± 5.0 db. Whenever a deviation exceeds the limit for which the computer is wired, this feature performs as follows:

(1) When the Teletypewriter is not in operation the test frame stops and sounds an alarm.

(2) When the Teletypewriter is recording all measurements, the letter U is added in a separate column at the end of the test record. The letter stands out on the record to permit quick spotting of trunks with abnormal deviations.

(3) By means of a control key, a transmission test record can be printed only for those trunks whose deviation exceeds the computer checking limit or which are "noisy" at either end.

Teletypewriter Record

The Teletypewriter is put into operation by means of a key on the test frame. When this key is normal, no records are printed. Under this condition a trouble causes the test frame to stop and sound an alarm. When the Teletypewriter is operating it prints various records and a minor operational trouble may result only in a record, without an alarm. Each record occupies a separate line on the tape. Each line starts with the four-digit trunk identification number in the first column. Fig. 7 shows a short specimen of the the Teletypewriter record.

When the pass busy key on the test frame is in its nonoperated position, the Teletypewriter will print the trunk identification number, followed by the letter B, for each trunk passed over without test because it was busy. This is done on both operational and transmission test cycles. When the pass busy key is operated no record is made of busy trunks passed without test.

During operational tests no record is printed for trunks which are

satisfactory. Troubles during either operational or transmission test cycles result in a record of the trunk identification number followed by a cue letter in a separate column denoting the nature of the trouble. This may be a single line record or a double line record for a repeat test on the same trunk as previously discussed. For example, in Fig. 7, the letter Y in the second line indicates that on trunk 1267 the far end was unable to complete its transmission measurement successfully. The letter A in lines 3 and 4 indicates that the test frame was unable to establish a connection over trunk 1293 on either its first or second attempt. The record of transmission tests is printed in several columns. Reading from left to right (see Fig. 7) these are (1) trunk identification number, (2) specified net loss, (3) deviation in the far-to-near direction together with the sign, and (4) deviation in the near-to-far direction together with the sign. In columns 2, 3, and 4 the decimal points are omitted and the ten's digits are omitted when they are zero (0). Column 5 will contain an N if the far end is "noisy" or the letter U if the deviation in the far-to-near direction exceeds the computer check limits, preference being given to N if both conditions occur on the same trunk. Likewise column 6 contains an N if the near end is "noisy" or a U if the deviation in the near-to-far direction exceeds the computer check limits. Transmission test cycles will, of course, include a trouble record whenever an operational trouble is encountered or whenever the transmission test cannot be completed successfully.

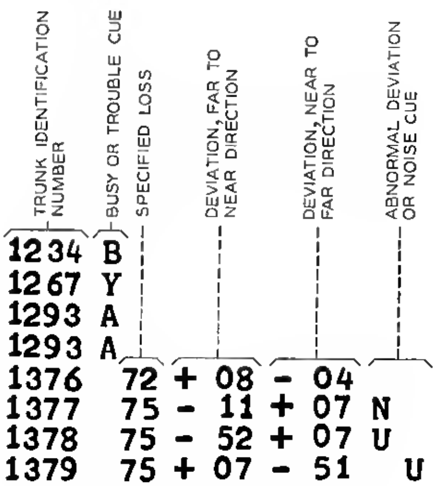

Fig. 7 — Teletypewriter test record.

APPLICATION

Maximum benefits can be derived from the automatic testing equipment by locating it at points having a considerable number of intertoll trunks. This suggests that the near-end installations be placed in offices in larger cities and far-end installations be placed at points with enough trunks available to near-end equipment to justify the far-end equipment. As has been indicated the far-end equipment can operate with either an automatic transmission test and control circuit or with a test board attendant at the opposite end. Therefore, once an office has been supplied with far-end test equipment, all incoming and two-way dial type intertoll trunks from offices provided with near end equipment can be tested on a fully automatic basis and all incoming and two-way dial type intertoll

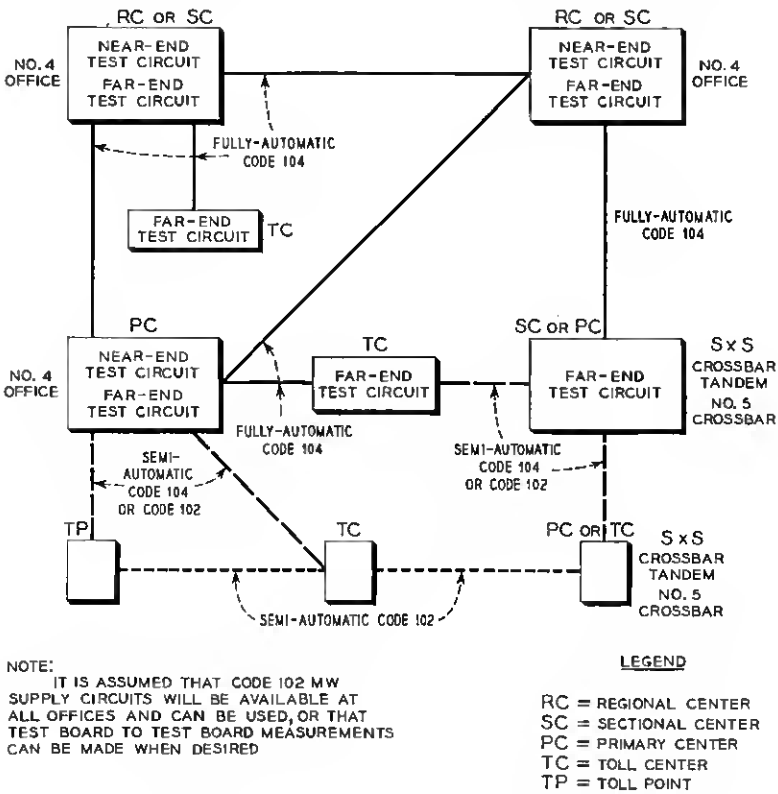

Fig. 8 — Typical layout for automatic testing.

trunks from other toll offices can be tested on a semi-automatic basis from the toll test board in the distant office.

Fig. 8 shows a possible application of automatic test circuits. In such an application, all No. 4 type toll crossbar offices would have both near-end and far-end equipments. Other offices would have far-end equipment only when they have a sufficient number of direct trunks to No. 4 type offices to justify its use. The several types of tests which would be possible are indicated in the illustration.

It can be seen that a well distributed number of near-end and far-end test circuits will make it possible to test automatically a large percentage of the intertoll trunks throughout the country. This is particularly true in the more populous sections, where the concentration of trunks results in the probability of toll centers having trunks to more than one office furnished with near-end equipment.

ACKNOWLEDGMENTS

Automatic intertoll trunk testing arrangements, including transmission tests, are the result of the ideas, efforts and experiences of many people concerned with intertoll switching and maintenance problems throughout the Bell System. Mr. L. L. Glezen and Mr. L. F. Howard deserve particular mention in this regard. Specific credit should also be given to Mr. B. McKim and Mr. T. H. Neely for the basic scheme of two-way transmission measurements and accuracy checks and to Mr. C. C. Fleming for the design of the amplifier and amplifier-rectifier. Appreciation is given to various departments of the American Telephone and Telegraph Company for their assistance during the development and trial of this equipment. Mention should also be made of the hearty cooperation and aid given by the A.T. & T. and Associated Company plant forces during the field trial of automatic transmission testing.